

Noble Liquid Detector R&D at BNL

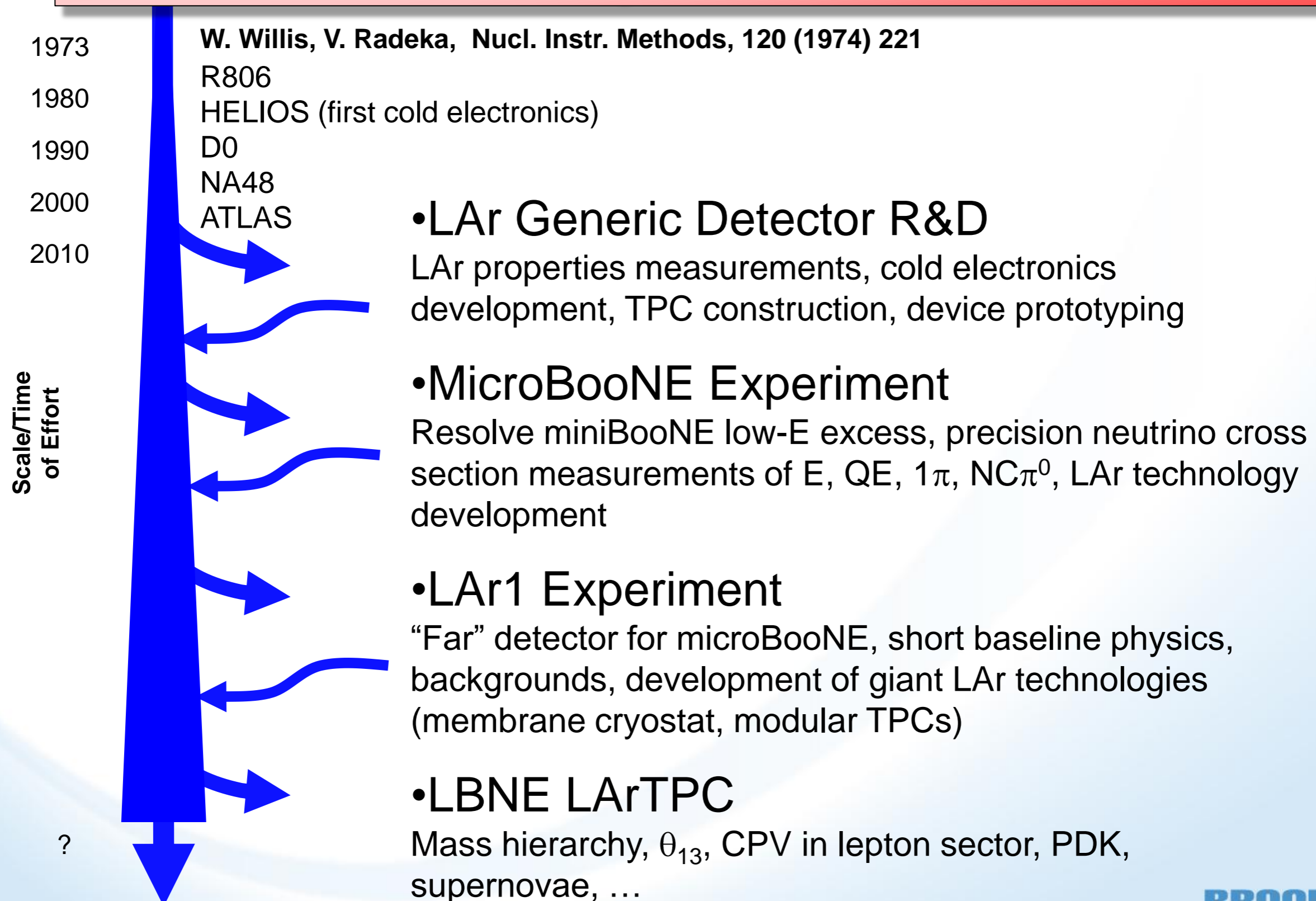
Craig Thorn

*DOE Detector R&D Program Manager Visit
October 3, 2012*



Long Drift Noble Liquid Detectors

Leading to Giant LAr TPCs



Noble Liquid R&D Effort for LAr TPCs

Basic properties measurements in LAr, Ne, Xe

Charge transport

- ✓ *Electron diffusion*
- ✓ *electron attachment*
- ✓ *Recombination*
- ✓ *Positive ion mobilities*

Light transport

- ✓ *optical absorption*
- ✓ *Rayleigh scattering*

All are supported by KA15

LAr TPC Effort at BNL

Cryogenics, TPC, Cold Electronics ↔ LAr Detector R&D, MicroBooNE, LAr1, LBNE FD

MicroBooNE Project management:

Craig Thorn	Deputy Project Manager for AD
Sue Duffin	L2 Manager for Cryostat
Hucheng Chen	L2 Manager for Readout Electronics
George Mahler	L2 Manager for Detector Integration

LBNE Project management:

Mary Bishai	Project Scientist
Penka Novakova	Controls Specialist
Jeff Dolph	Project Engineer
Milind Diwan	Collaboration Co-Spokesperson

Jim Stewart	L2 Manager for FD
Bo Yu	L3 Manager for TPC
Craig Thorn	L3 Manager for Cold Electronics

LAr1 Experiment members:

H. Chen, C. Thorn, D. Lissauer, V. Radeka, B. Yu,
G. Mahler, S. Rescia, S. Duffin, Y. Li

Supported by KA15

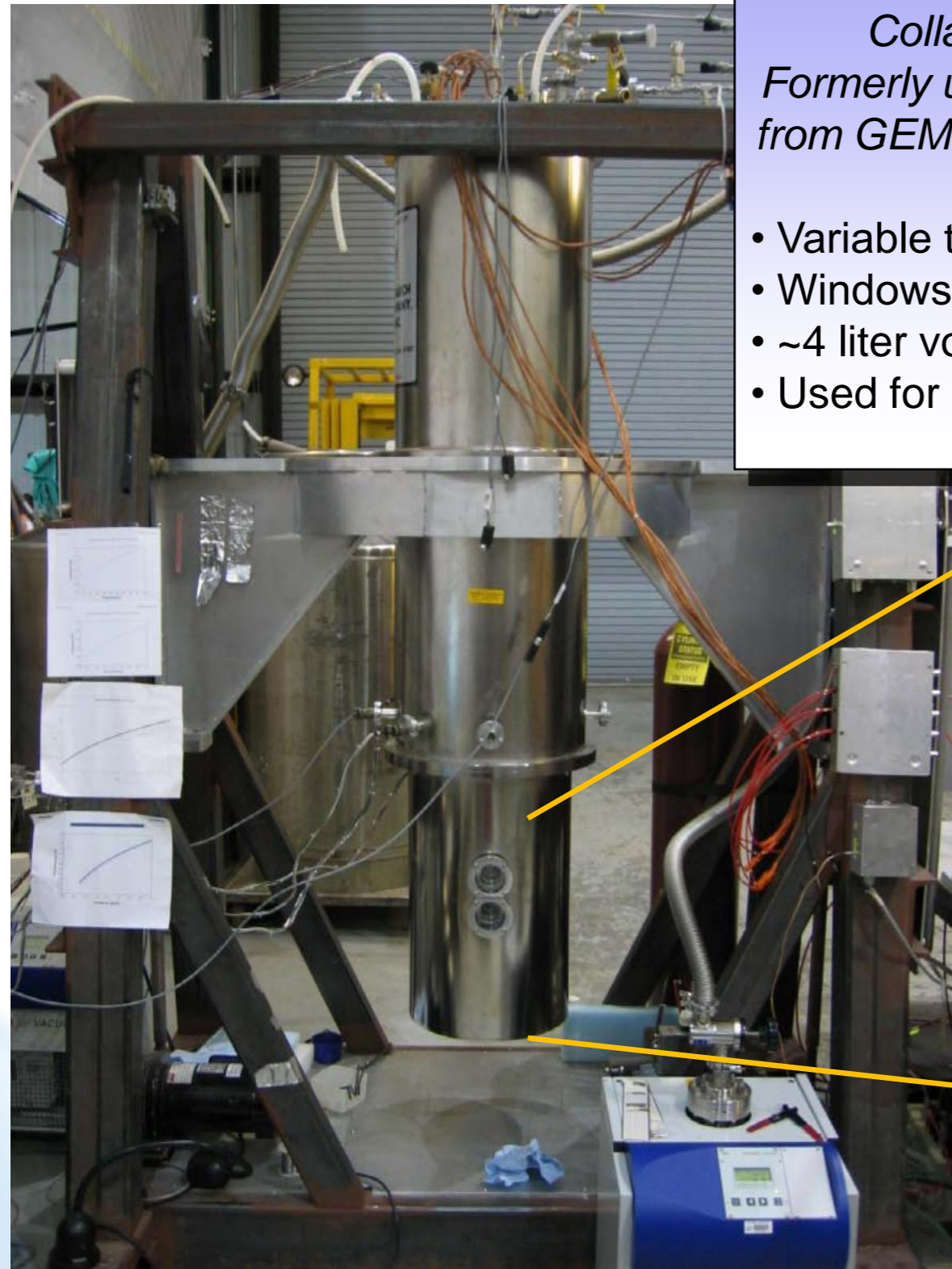
Instrumentation Division:

Veljko Radeka	Division Head
Gianluigi DeGeronimo	ASiC design & development
Shaorui Li	
Neena Nambiar	
Emerson Vernon	
Jack Fried	
Sergio Rescia	
Joe Mead	
Trivini Rao	Optics, QE
Thomas Tsang	
Bo Yu	TPC Design
George Mahler (CAD)	

Physics Department:

Hucheng Chen	Electronics
Kai Chen	
Pierrot Bichoneau	
Sue Duffin	Cryostats & cryogenics
Jack Sondericker	
Anatoli Gordeev	
Jason Farrell	
Andres Ruga	
Francesco Lanni	LAr R&D
YiChen Li	
Bill Morse	
Harry Thiemann	
Craig Thorn	

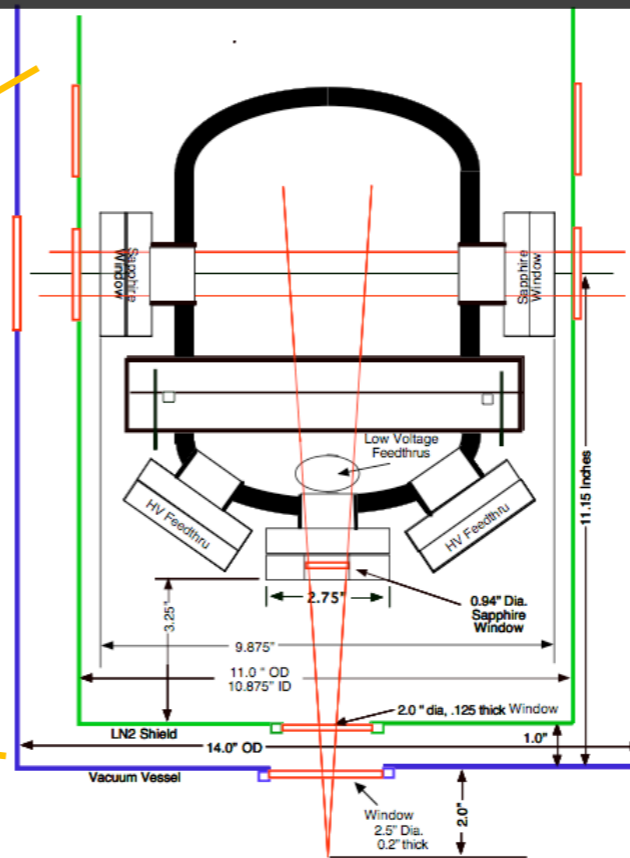
Charge and Light Production in Cold Supercritical Neon



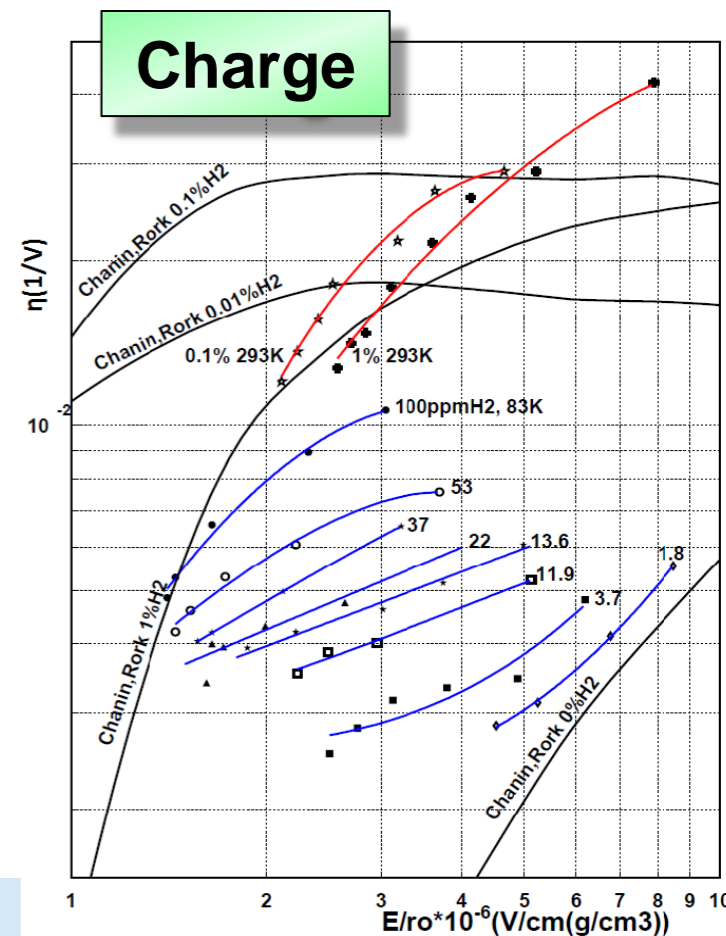
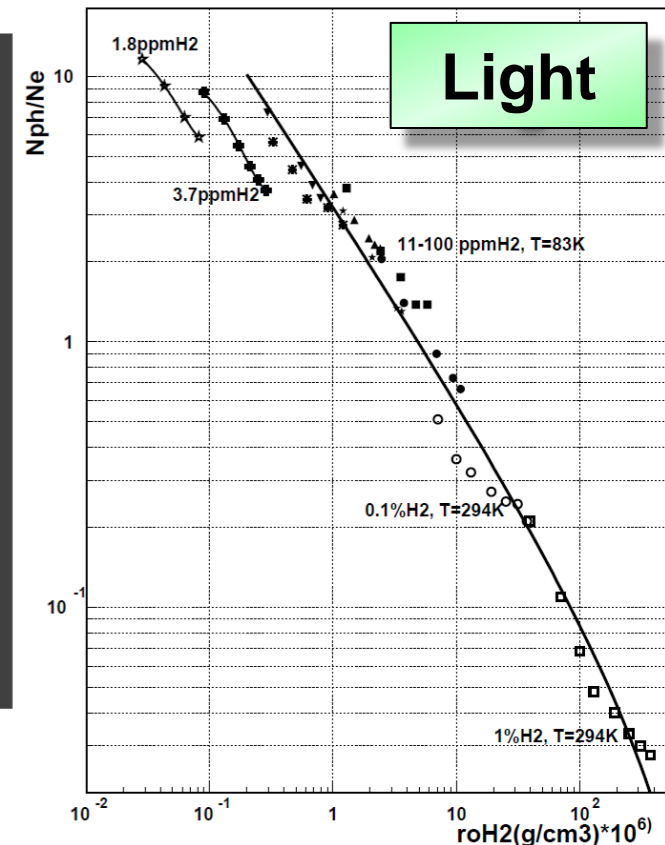
eBubble Cryostat

*Collaboration with Columbia U.
Formerly used for R&D on light production
from GEMs in high density supercritical Ne*

- Variable temp, high pressure cryostat
- Windows for optical measurements
- ~4 liter volume
- Used for charge and light measurements



High Pressure Cryostat

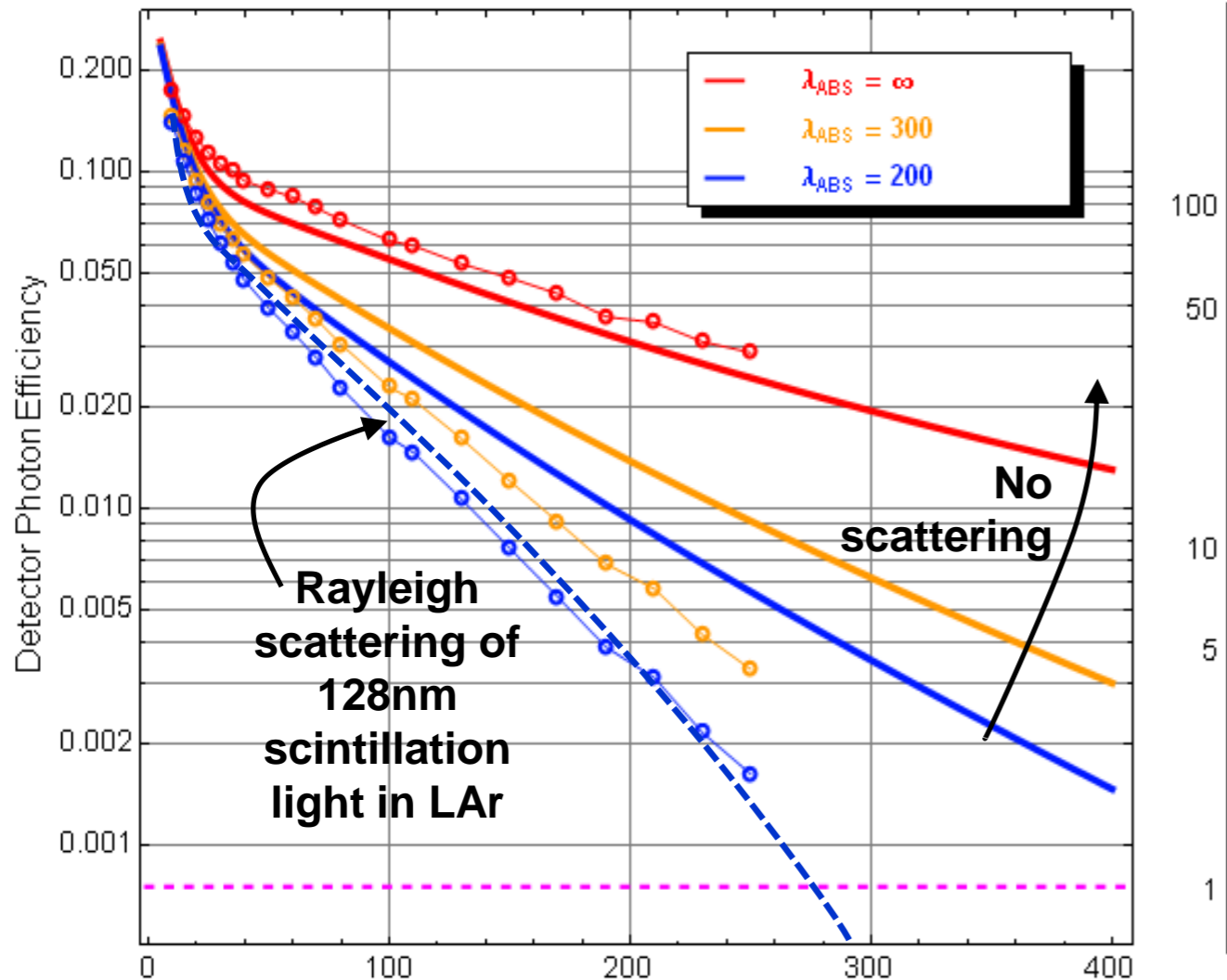


Generic LAr R&D Properties of LAr

Transport properties: scintillation light absorption and electron diffusion

Light detection in LAr

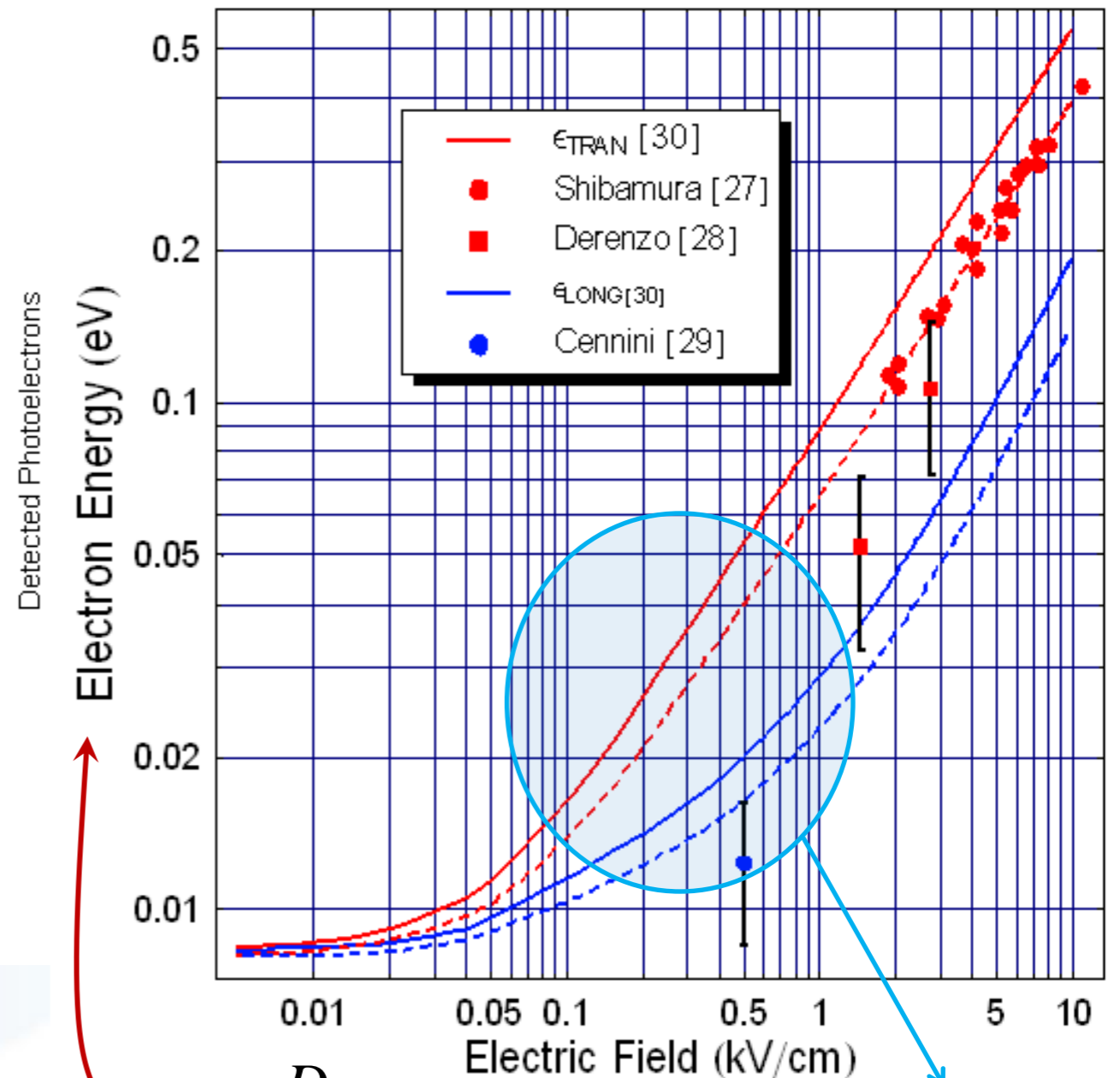
Net Photon Collection Efficiency w/ and w/o Rayleigh Scattering



Liquid	Wavelength (nm)	Scattering Length (m)		Absorption Length (m)
		Calculated	Measured	Deduced
Neon	80	60	-	-
Argon	128	95	66	200
Krypton	147	60	82	negative!
Xenon	174	30	29	>800

Diffusion of electrons in LAr

Electron Energy in LAr: Data + Theory of Artazhev

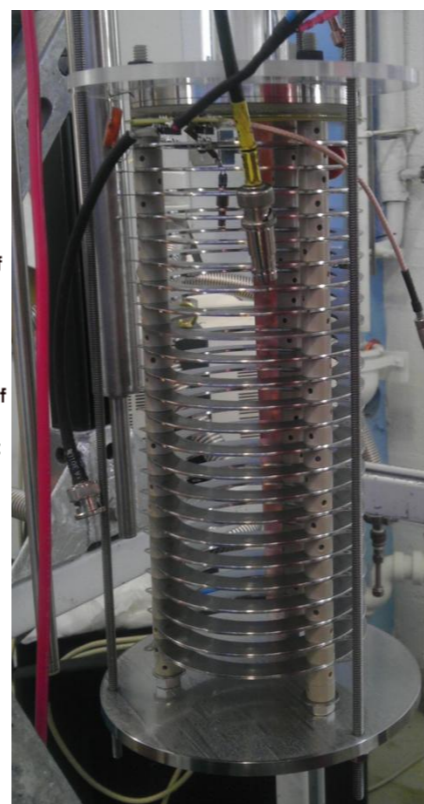
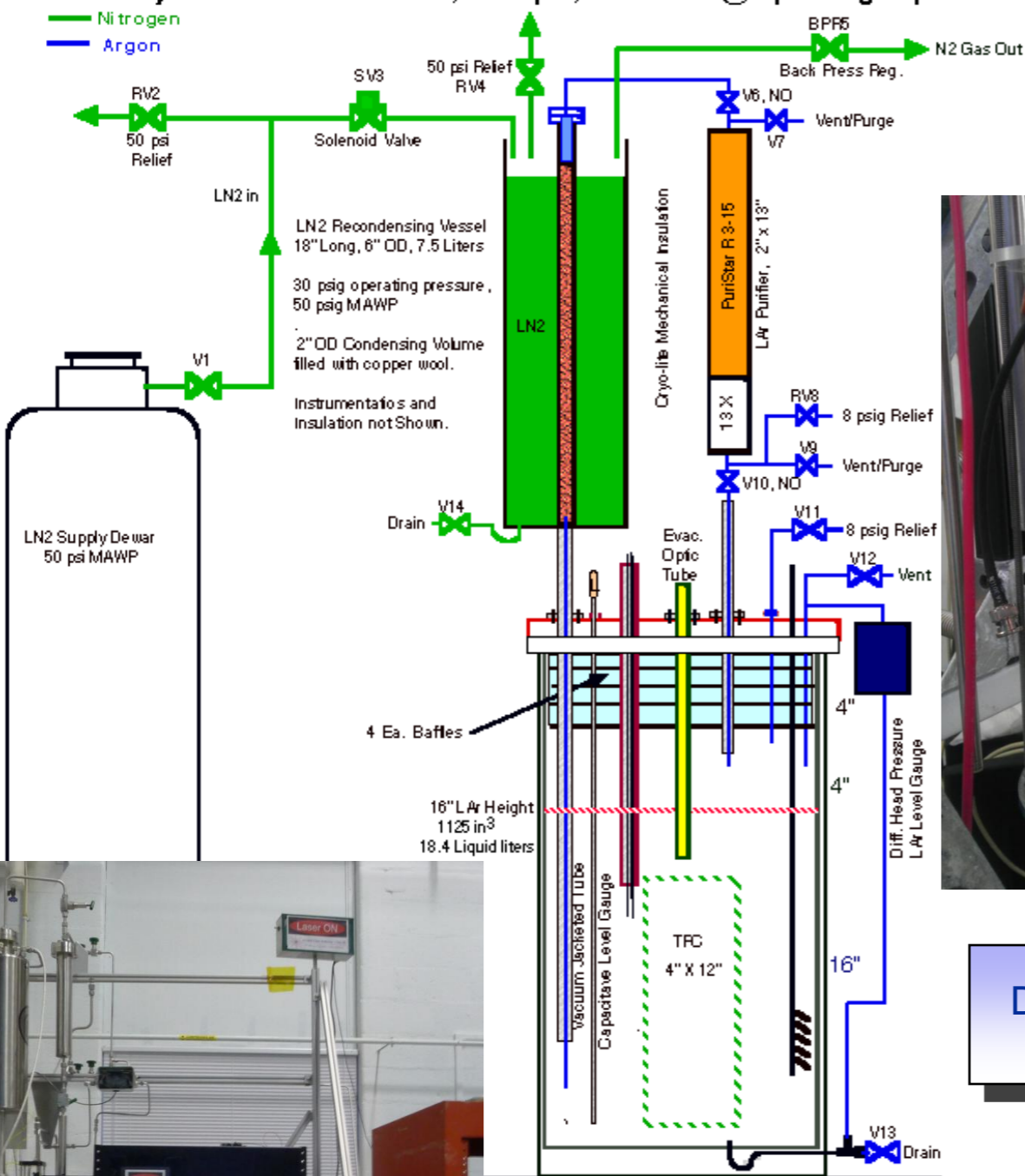


$$\varepsilon_e \equiv \frac{eD_e}{\mu_e}$$

~no data below 1.5 kV/cm

Electron Drift and Diffusion in LAr

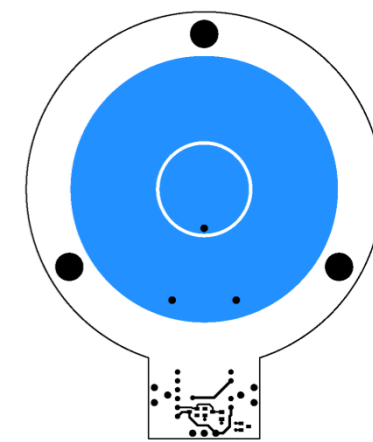
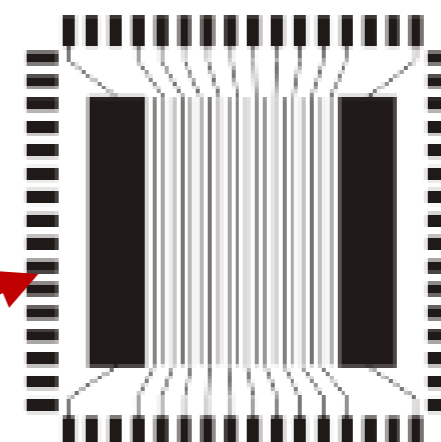
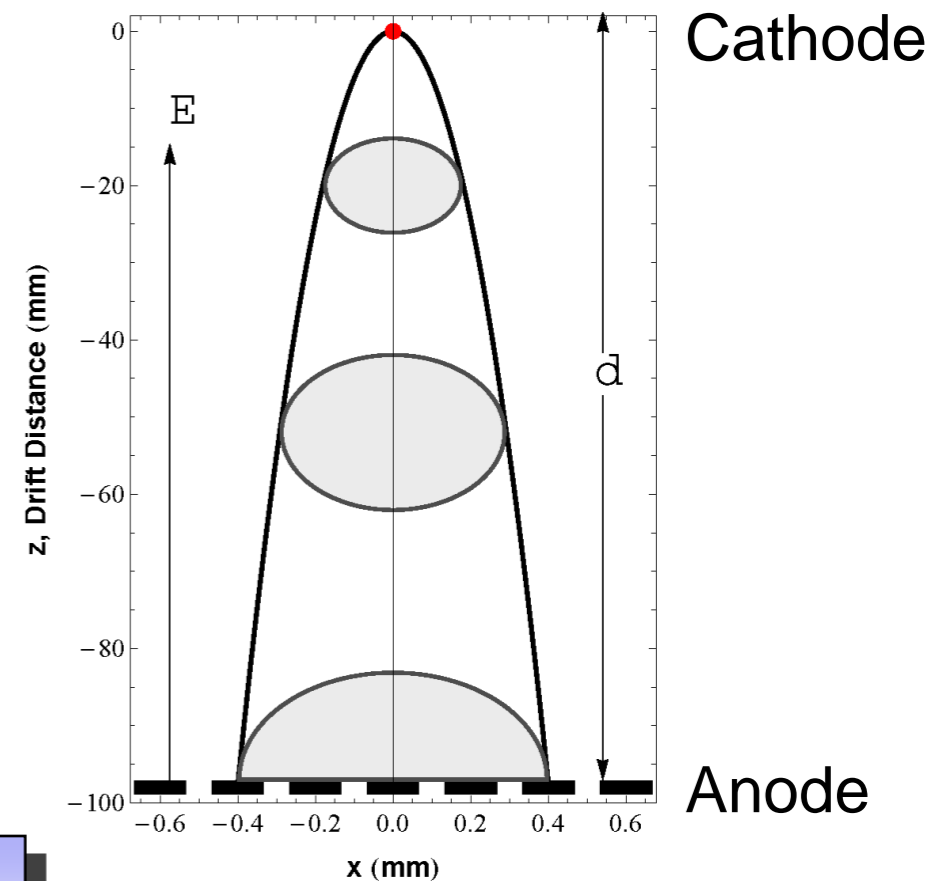
Modified Cryofab Dewar -- 9.46 ID, 24 Depth, 18.4 Liters @ Operating Depth



Drift stack above cryostat

Charge collection electrodes for Transverse diffusion (left) and Longitudinal diffusion (right)

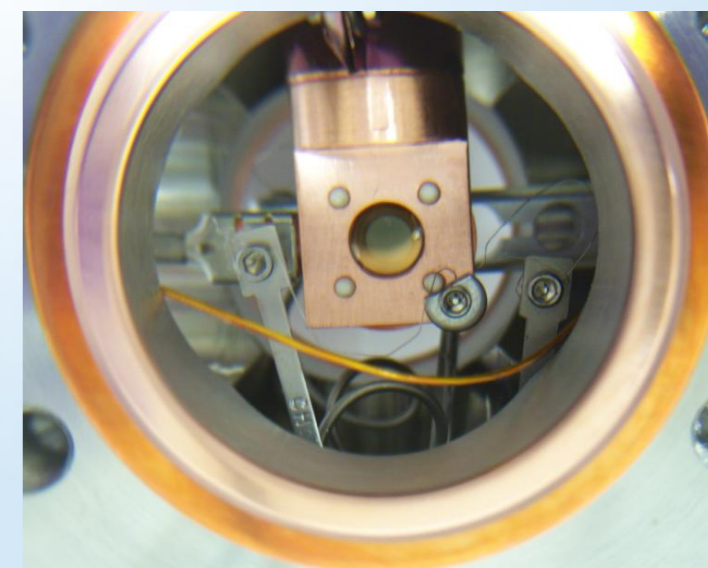
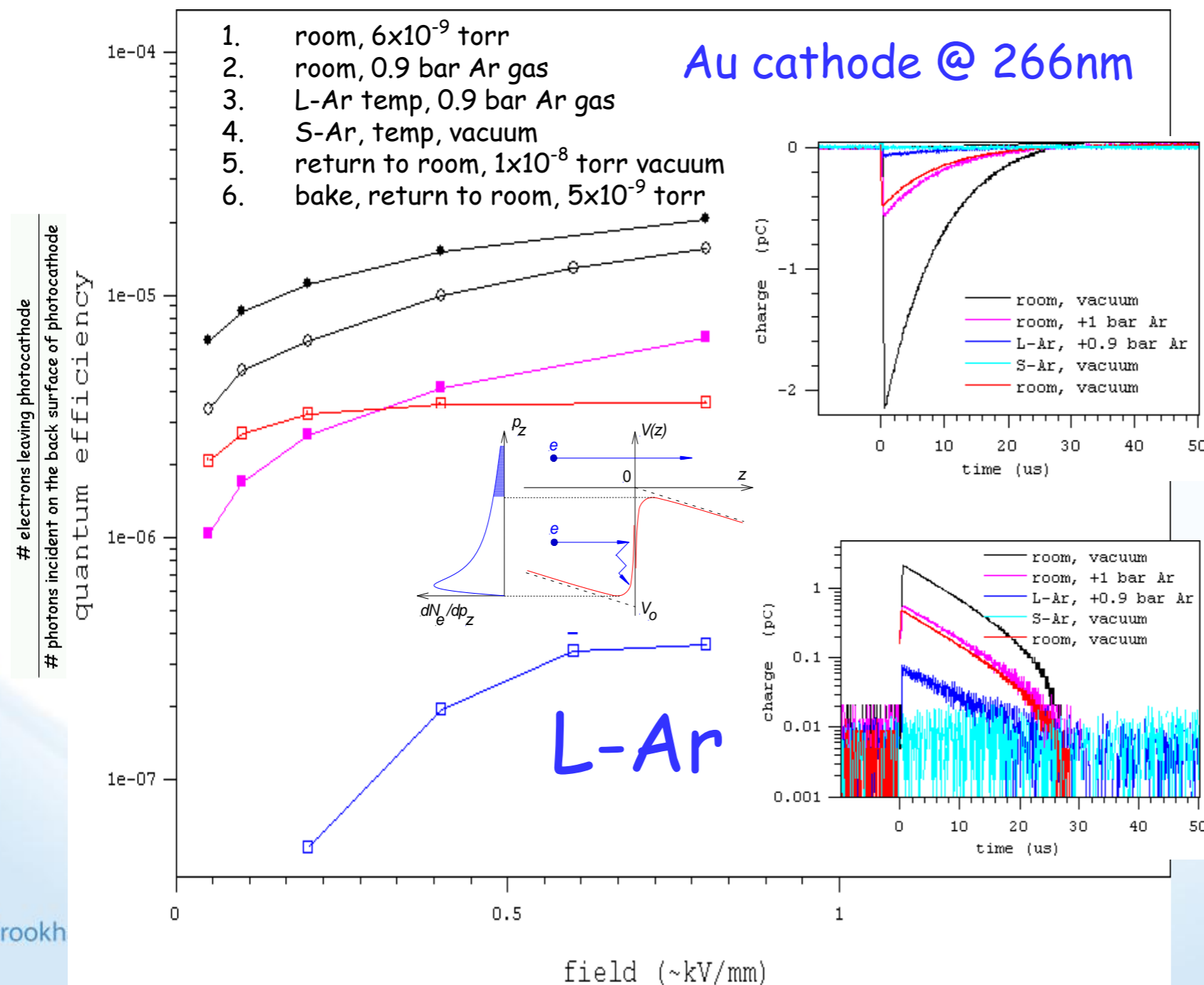
$$\varepsilon_e \equiv \frac{eD_e}{\mu_e} \quad \sigma = \sqrt{\frac{2Dz}{v}} = \sqrt{\frac{2\varepsilon z}{E}}$$



High Brightness Photocathodes in LAr

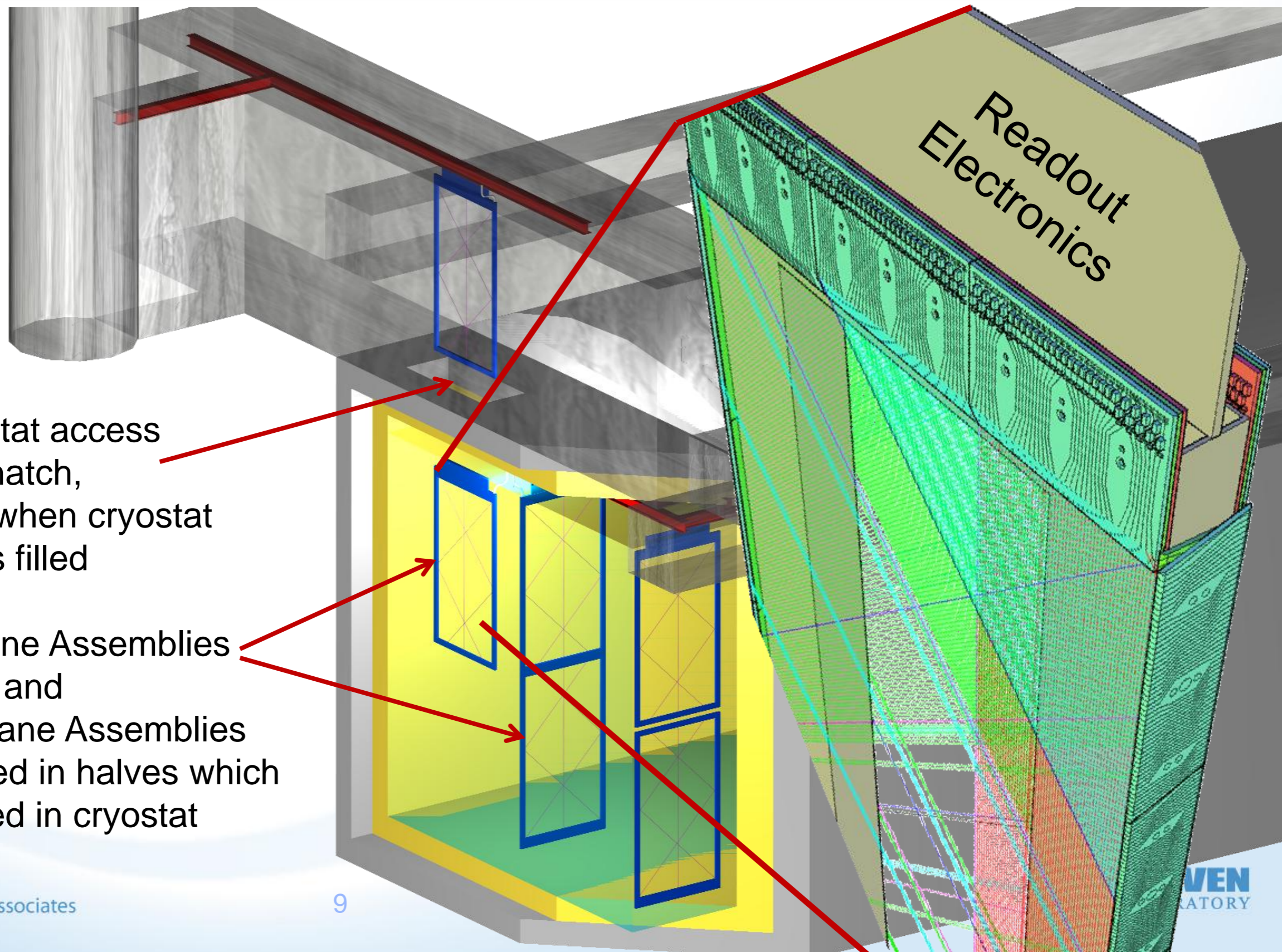
Extensive scientific and engineering expertise in Instrumentation Division in laser and photocathode techniques are being used to advance

R&D on photocathode materials to improve photon detector performance and for high-brightness electron sources in LAr



LBNE LAr10 Modular Design Concept

Cryostat end cut open to show assembly



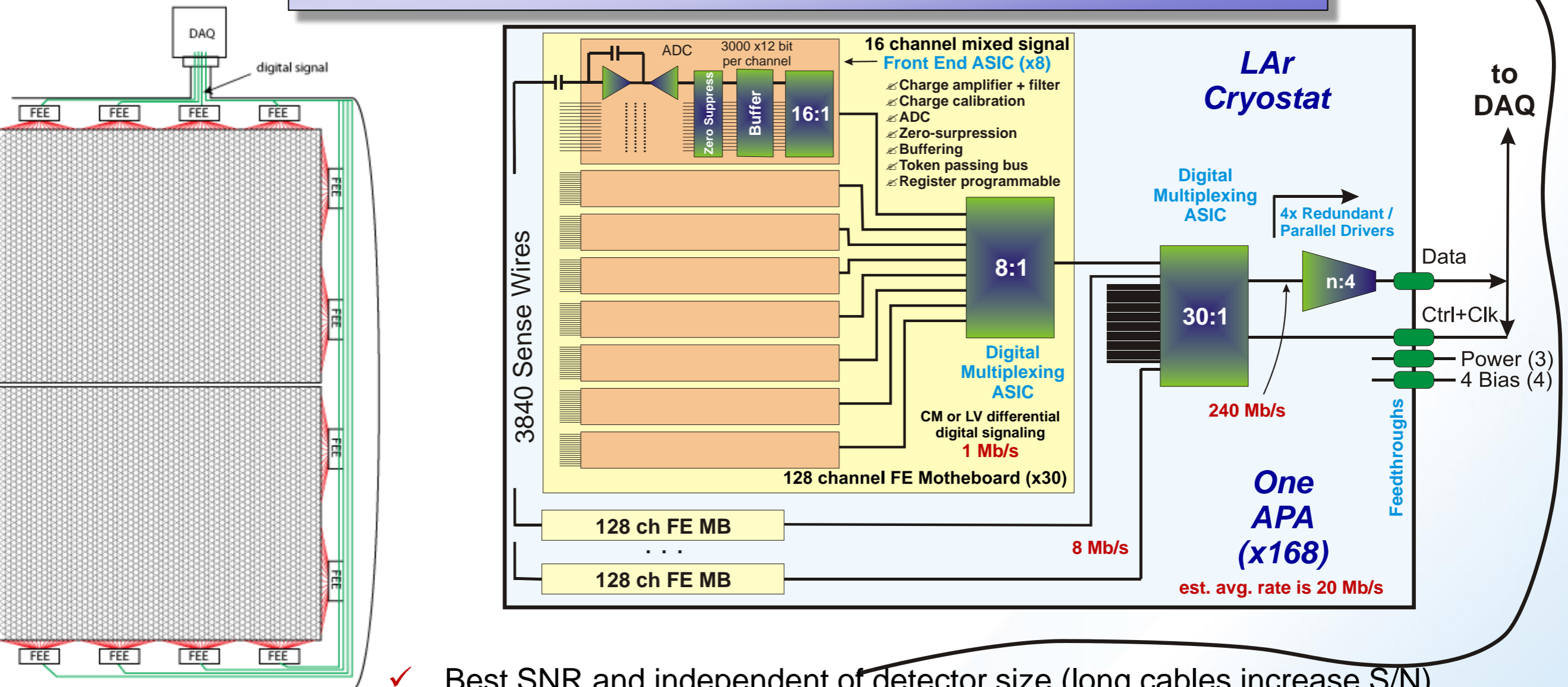
Cryostat access hatch,
plugged when cryostat
is filled

Anode Plane Assemblies
and
Cathode Plane Assemblies
are transported in halves which
are joined in cryostat

LAr TPC readout electronics

The Future - *Cold*

Cavern

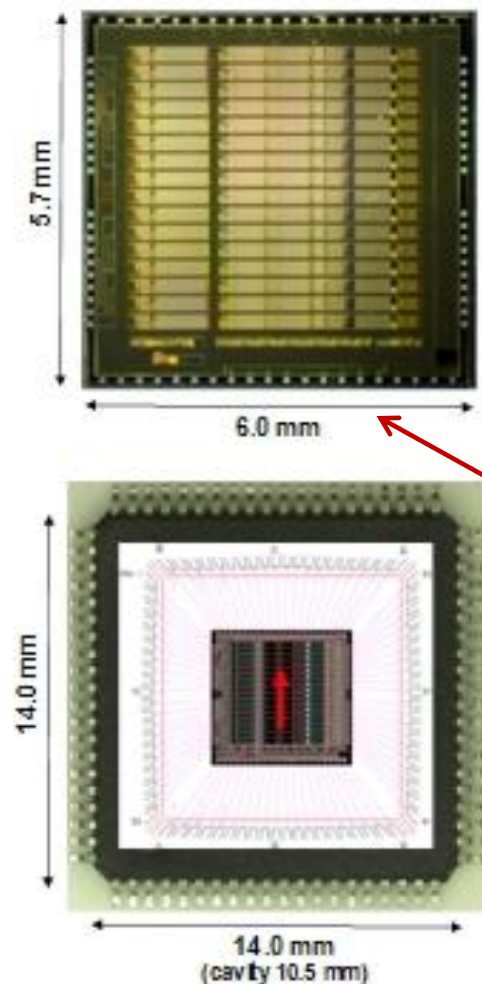


- ✓ Best SNR and independent of detector size (long cables increase S/N)
- ✓ Few cables in LAr, ensures LAr purity & long drift
- ✓ Few cryogenic feedthroughs (reduced heat load and cryogenic risk)
- ✓ Few interconnects & simple cabling (avoid signal loss)
- ✓ Modularity: electronics on detector can test / evaluate system through life-cycle
- ✓ Scalability: decouples cryostat and electronic designs (can optimize each)

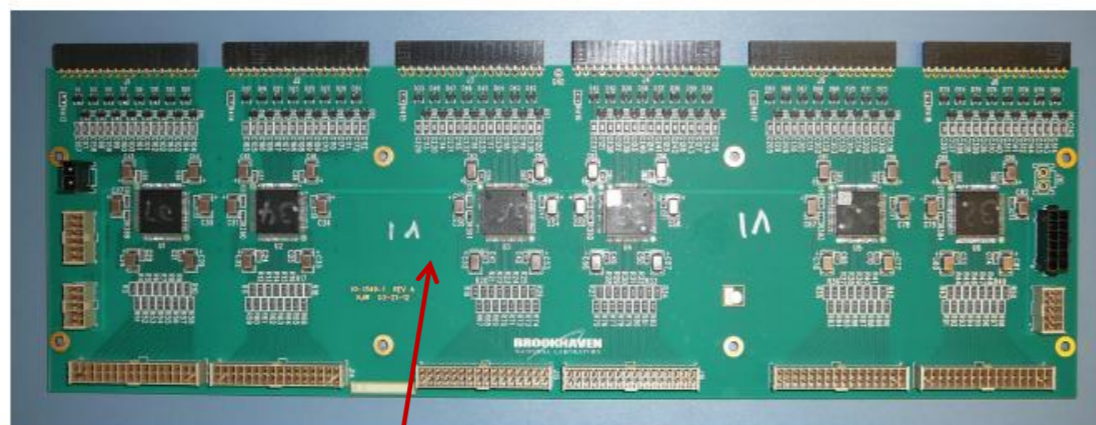
Cold electronics: better performance at lower cost and lower risk

LArTPC Readout ASIC Development

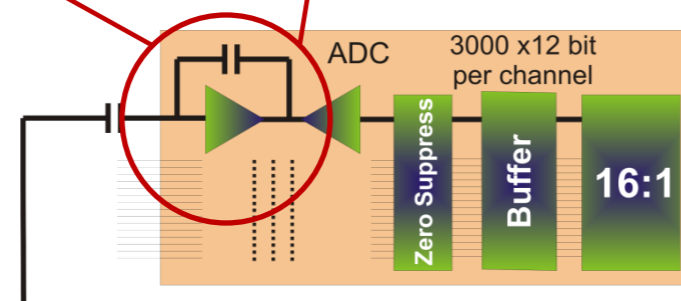
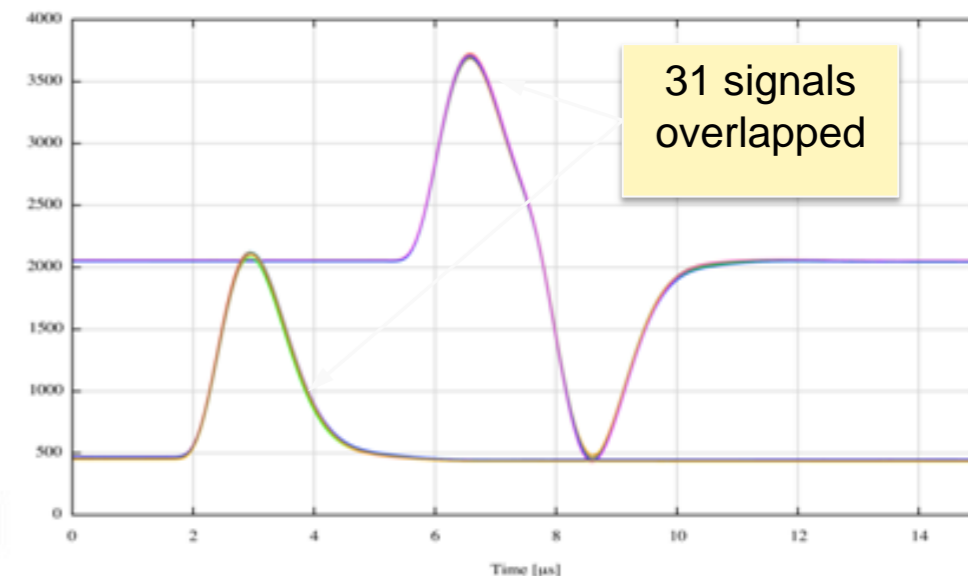
ASIC die & package



Prototype 128 channel Mother Board

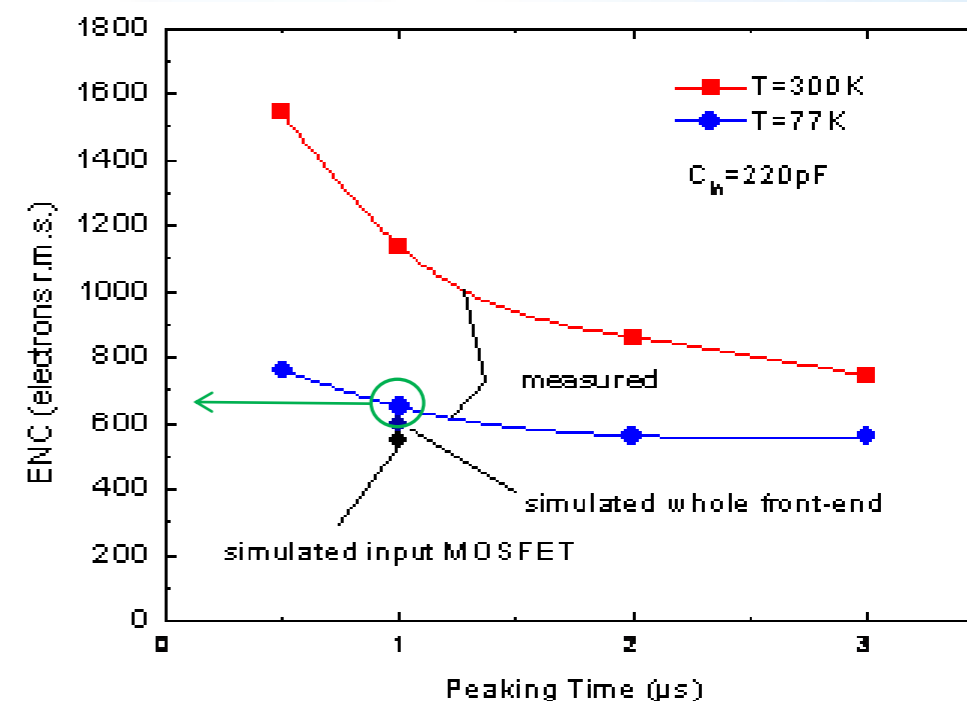
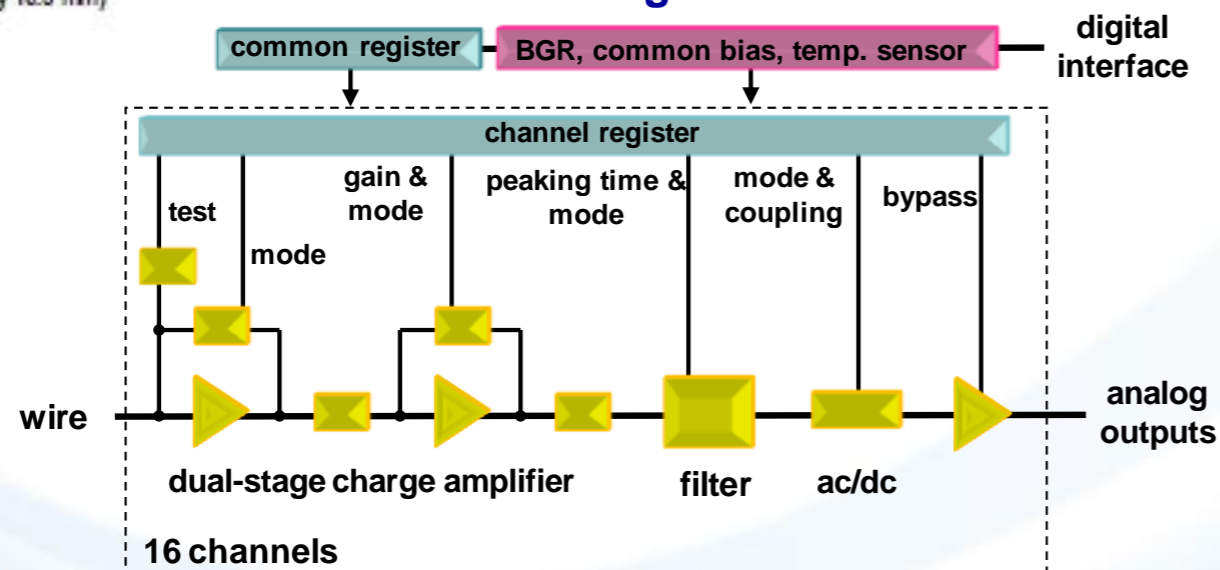


Prototype Vertical Cold Mother Board populated with 4th version of prototype ASICs



- Circuit performance is almost identical at 300K and 77K, except noise is ~2x lower
- Calibration capacitor on ASIC changes by ~0.5% from 300K to 77K

Block Diagram



16 channel FE CMOS ASIC

TSMC 180 nm Cold

Readout Electronics Characterization

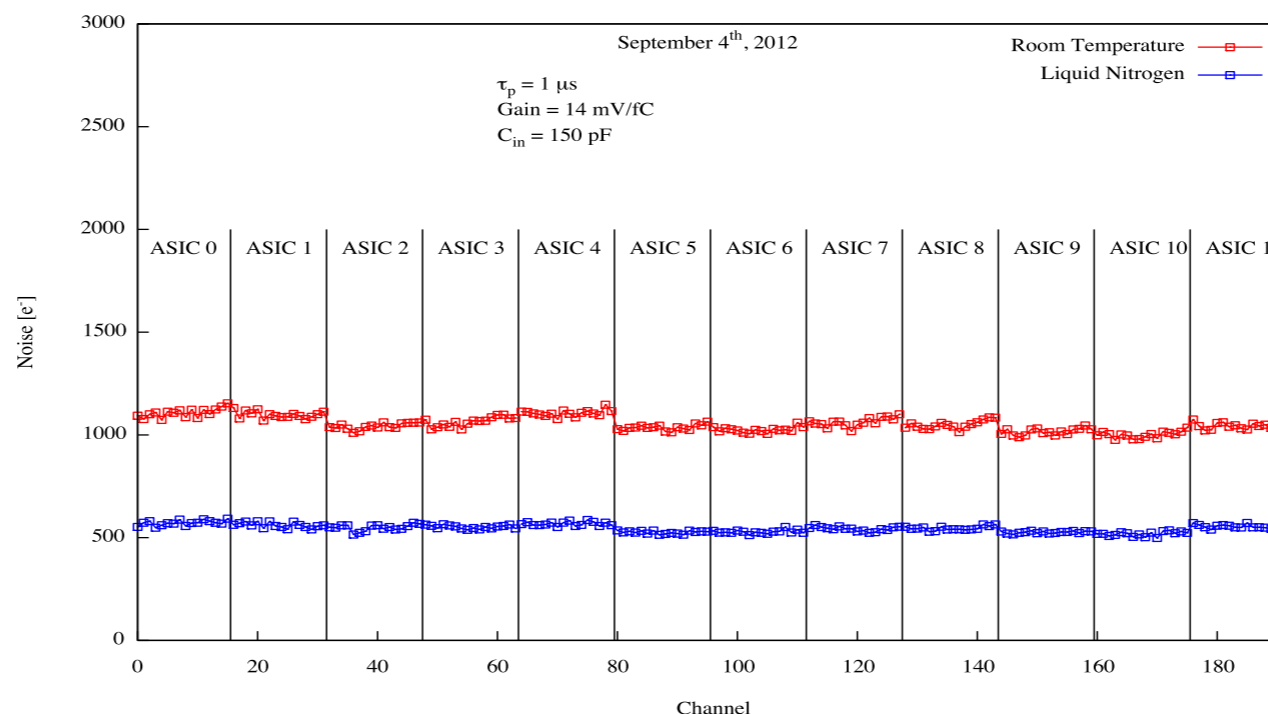
Signal processing in LAr

Design and characterization at low temperatures of analog front-end (FE) and ADC CMOS ASICs (with FNAL, MSU and SMU)

Power distribution in LAr

Characterization at LAr temperatures and long-term stability of ASIC and commercial voltage regulators. (ASIC design in collaboration with GIT)

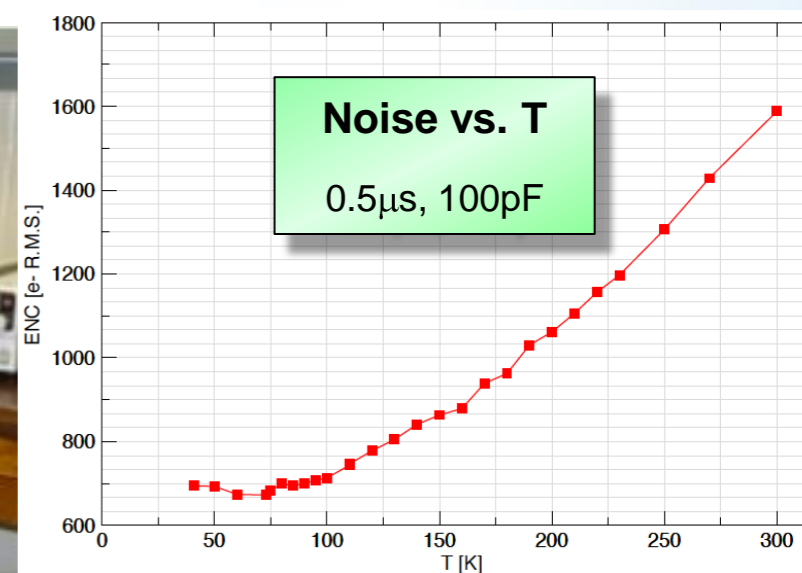
Test of 12th Mother Board with Twelve v4* ASICs Populated



Motherboard with twelve
16 channel FE ASICs

Noise is 550 e^- rms at 77K

Channel-to-channel gain
variation is $< \pm 2\%$



Microelectronics Summary

- BNL has **extensive experience** in the design of **low-power, low-noise, mixed-signal** integrated circuits (more than **30 ASICs** in the past **10 years**)
- The design process is **defined and predictable**, characterized by high yield and high reliability for **operation from RT to 77K**
- **Long lifetime** in radiation and cryogenic environments can be achieved using appropriate design techniques and processes
- ***ASIC challenges for future large detector systems***
 - Operation in extreme environments – cryogenic, rad., space
 - Mixed analog/digital systems with low noise and high speed
 - High degree of data sparsification, compression and multiplexing

Goals for the next year

- ✓ Transverse and longitudinal electron diffusion measurements
- ✓ Electron attachment cross section measurements for common LAr impurities
- ✓ Construction of a cryostat for optical characterization of impurities in LAr
- ✓ Absorption measurements of VUV light in LAr for common LAr impurities
- ✓ Characterization of full cryogenic readout system using existing front-end and ADC, with an FPGA